SEPARATION TEHCNIQUE OF CRUDE PALM OIL AT CLARIFICATION AREA VIA OPTIMUM PARAMETERS

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DECLARATION

I declare that this thesis is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………

Name : NURULHUDA BINTI KASIM

Date : 29 APRIL 2009

DEDICATION

To my beloved ones; my mother, father, siblings, and all my dearest friends

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Thank You.

ABSTRACT

The purpose of clarification is to separate the oil from its entrained impurities such as water, cell debris, fibrous material and non oily solid (N.O.S). In this study, optimum parameter such as temperature, effect of impeller, residence time and separation technique of crude palm oil is at clarification stage is determined. By using correct separation technique and condition, mill can maximize oil production and reduce oil losses. In this experimental, CPO are heated at 50°C, 60°C, 70°C, 80°C, 90°C, 110°C and 120°C for optimum temperature determination using water shaker batch. Experimentally, the results proved that by using 95°C for heating, CPO took the shortest time for separation. Difference size beakers also tested while separation. As larger the surface area of beaker, shorter time is taken for CPO separation. Otherwise the volume of CPO is directly proportional to the separation time. The present of impeller also enhances the separation of oil and sludge thus reduced the oil content in underflow while the pure oil obtained is increased.

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ABSTRAK

Penjernihan berfungsi untuk memisahkan minyak daripada bendasing seperti air, debris, fiber dan pepejal bukan minyak. Dalam kajian ini, optima parameter seperti suhu, kesan pemutaran, masa penahanan dan teknik pemisahan minyak kelapa sawit mentah ditentukan. Dengan menggunakan kaedah pemisahan yang betul, kilang dapat memaksimumkan pengeluaran miyak sawit dan mengurangkan kehilangan minyak. Dalam eksperimen ini, minyak sawit mentah di panaskan menggunakan pemanas air seragam pada suhu 50°C, 60°C, 70°C, 80°C, 90°C, 110°C dan 120°C untuk menentukan suhu optima. Keputusan menunjukkan pada suhu 95°C, masa untuk pemisahan diambil adalah paling singkat. Semakin besar luas permukaan bikar, semakin singkat masa diambil untuk pemisahan, manakala semakin banyak isipadu minyak sawit mentah semakin lama masa diambil untuk pemisahan. Kehadiran pemutar juga boleh menggalakkan pemisahan minyak dan enap cemar sepertimana kurang kandungan minyak di saluran bawah tangki penjernihan dan lebih banyak minyak tulen diperolehi.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.0 Introduction

Palm oil is extracted from the mesocarp of the fruit of the palm *Elaeis guineensis*. There are a few varieties of this plant but Tenera, which is a hybrid of the Dura and the Pisifera, present abundantly through out the whole Peninsular. Productivity of plantations is high (typically 15 t/ha of fresh fruit bunches in Ivory Coast, 20-30 t/ha in Malaysia and Indonesia).

From the fruit two distinct types of oils are produced palm oil and palm kernel oil. Both are edible oils but with very different chemical composition, physical properties and applications. Each palm fruit produces about 90% palm oil and 10% palm kernel oil. The mesocarp comprises about 70 - 80% by weight of the fruit and about 45 - 50% of this mesocarp is oil. The rest of the fruit comprises the shell, kernel, moisture and other non fatty fiber. The extracted oil is known as crude palm oil (CPO) which until quite recently was known as the golden commodity.

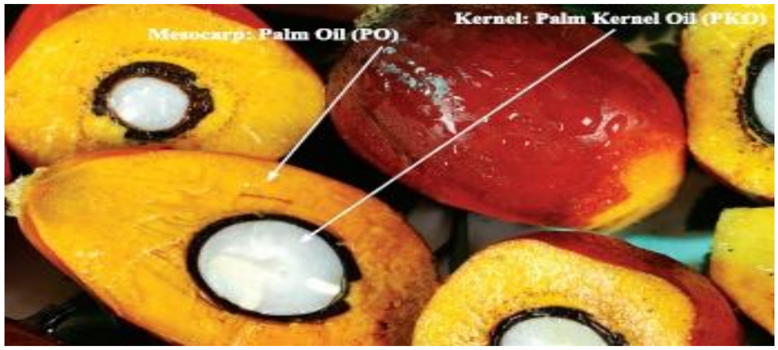


Figure 1.1 Palm Oil Fruitlets

The most important for oil palm mill is to maximize oil recovery to fulfill the demand. Global consumption of major oils and fats has been increasing over the last few years, driven by growing consumer demand, especially in the developing world. Usage of vegetable edible oils also increasing which it is uses in replacing animal fats in foods, feeds and other non food applications. Palm oil is the fastest growing segment of the world edible oil production base, growing from less than 6 million MT in 1983/1984 to more than 27 million MT in 2002/2003. In the five-year period 1999/2000 to 2002/2003, palm oil production increased at an average of 9.5% per year. In comparison, the total supply of oils and fats only grew at an average annual growth rate of about 4% in the same period, to a total of 122 million MT.

Fresh fruit from plantation need to be sent quickly to the mill for processing to obtain crude palm oil. There are several stages of processing the extraction of palm oil from fresh fruit bunches. These include reception, sterilization, bunch stripping, digestion, oil extraction and finally clarification and purifications. (Figure 1.2)

1.01 Reception

Fresh fruit arrives from the field as bunches or loose fruit. The fresh fruit is normally weighing on a scale so that quantities of fruit arriving at the processing site may be checked. Large installations use weighbridges to weigh materials in trucks. The quality standard achieved is initially dependent on the quality of bunches arriving at the mill. The mill cannot improve upon this quality but can prevent or minimize further deterioration.

1.02 Sterilization

Sterilization or cooking means the use of high-temperature wet-heat treatment of looses fruit. Cooking normally uses hot water; Sterilization uses high pressurized steam (120 to 140°C at 40psi) that subject to freshly harvested fruit bunches with a minimal delay to inactivate the lipolytic enzymes that cause oil hydrolysis and fruit deterioration. The cooking action serves several purposes. Fruit cooking weakens the pulp structure, softening it and making it easier to detach the fibrous material and its contents during the digestion process.

- The high heat is enough to partially disrupt the oil-containing cells in the mesocarp and permits oil to be released more readily.
- The moisture introduced by the steam acts chemically to break down gums and resins. The gums and resins cause the oil to foam during frying. Some of the gums and resins are soluble in water. Others can be made soluble in water, when broken down by wet steam (hydrolysis), so that they can be removed during oil clarification. Starches present in the fruit are hydrolyzed and removed in this way.

1.03 Bunch Stripping

At this stage, the separating of fruits from bunch by mechanical stripping using rotary drum.

1.04 Digestion

Sterilized and separated fruit then undergo digestion. Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells. The digester commonly used consists of a steam-heated (80ºC-90ºC) in cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. Digestion helps to reduce the viscosity of the oil, destroys the fruits' outer covering (mesocarp) and loosening the mesocarp from the nuts.

1.05 Oil Extraction

The crude oil is extracted from the digested fruit mash using screw press without breakage the kernel. The extracted liquid and nuts are discharged from the screw press. The extracted oil contains amount of water, solids and dissolved impurities that must be removed. The fiber particles from the pressed crude oil are first removed by passing the oil over a vibrating screen. Here, sand and dirt are allowed to settle. Water is removed by settling or centrifuging and finally by vacuum drying.

1.06 Clarification

Clarifying and drying of oil. The main point of clarification is to separate the oil from its entrained impurities. The fluid coming out of the press is a mixture of palm oil, water, cell debris, fibrous material and 'non-oily solids'. Because of the non-oily solids the mixture is very thick (viscous). Hot water is therefore added to the press output mixture to thin it. The dilution (addition of water) provides a barrier causing the heavy solids to fall to the bottom of the container while the lighter oil droplets flow through the watery mixture to the top when heat is applied to break the emulsion (oil suspended in water with the aid of gums and resins). Water is added in a ratio of 3:1. The diluted pass through a screen to remove coarse fibers. The screened mixture is boiled from one or two hours and then allowed to settle by gravity in the large tank so that the palm oil, being lighter than water, will separate and rise to the top. The clear oil is decanted into a reception tank. This clarified oil still contains traces of water and dirt. To prevent increasing FFA through autocatalytic hydrolysis of the oil, the moisture content of the oil must be reduced to 0.15 to 0.25 percent. Re-heating the decanted oil in a cooking pot and carefully skimming off the dried oil from any engrained dirt removes and any residual moisture. Continuous clarifiers consist of three compartments to treat the crude mixture, dry decanted oil and hold finished oil in an outer shell as a heat exchanger.

1.07 Oil Storage

In large-scale mills the purified and dried oil is transferred to a tank for storage prior to dispatch from the mill. Since the rate of oxidation of the oil increases with the temperature of storage the oil is normally maintained around 50°C, using hot water or low-pressure steam-heating coils, to prevent solidification and fractionation. Iron contamination from the storage tank may occur if the tank is not lined with a suitable protective coating. Small-scale mills simply pack the dried oil in used petroleum oil drums or plastic drums and store the drums at ambient temperature.

1.08 Kernel recovery

The residue from the press consists of a mixture of fiber and palm nuts. The nuts are separated from the fiber by hand in the small-scale operations. The sorted fiber is covered and allowed to heat, using its own internal exothermic reactions, for about two or three days. The fiber is then pressed in spindle presses to recover second grade (technical) oil that is used normally in soap-making. The nuts are usually dried and sold to other operators who process them into palm kernel oil. The sorting operation is usually reserved for the youth and elders in the village in a deliberate effort to help them earn some income.

Large-scale mills use the recovered fiber and nutshells to fire the steam boilers. The super-heated steam is then used to drive turbines to generate electricity for the mill. For this reason it makes economic sense to recover the fiber and to shell the palm nuts. In the large-scale kernel recovery process, the nuts contained in the press cake are separated from the fiber in a depricarper. They are then dried and cracked in centrifugal crackers to release the kernels. The kernels are normally separated from the shells using a combination of winnowing and hydrocyclones. The kernels are then dried in silos to a moisture content of about 7 percent before packing.

During the nut cracking process some of the kernels are broken. The rate of FFA increase is much faster in broken kernels than in whole kernels. Breakage of kernels should therefore be kept as low as possible, given other processing considerations.

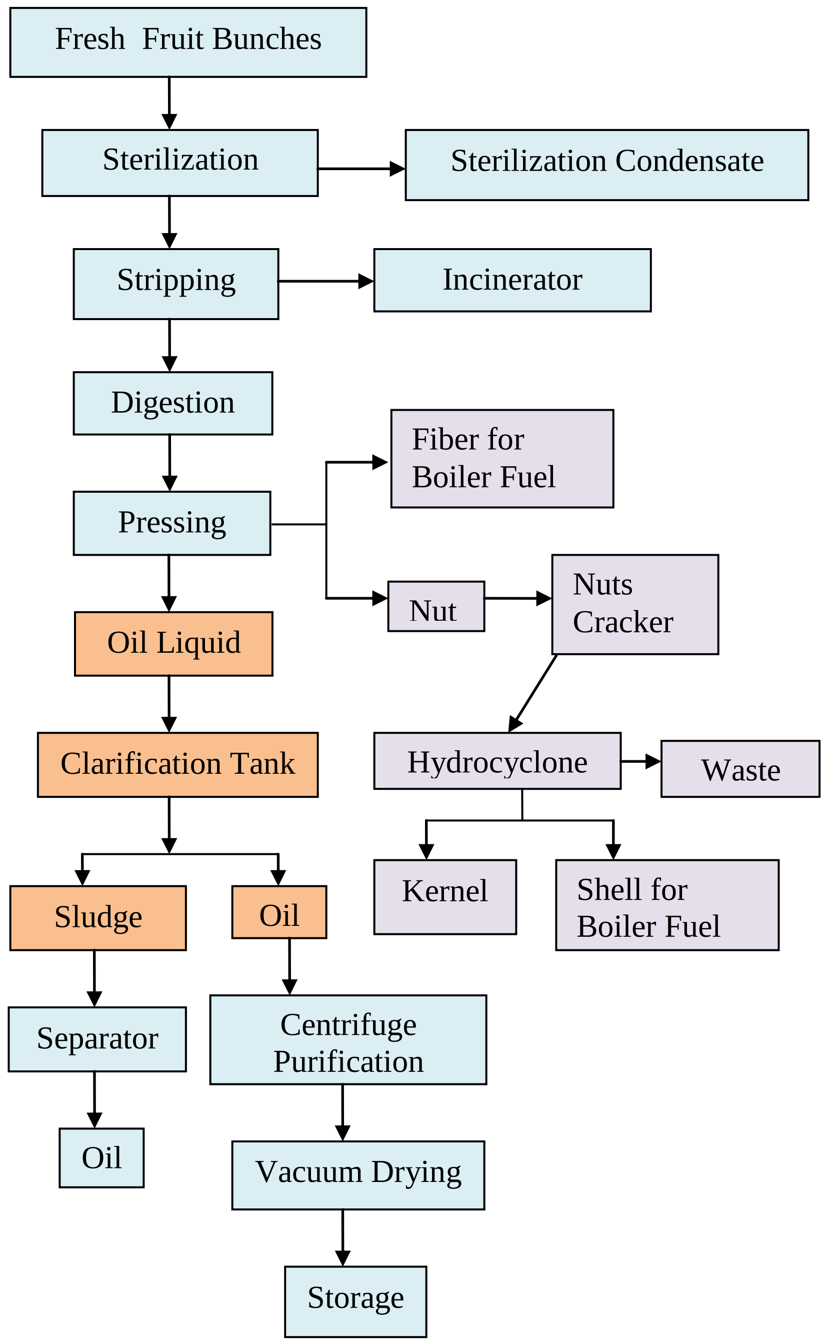


Figure 1.2 A Block Flow Diagram of The Palm Oil Mill Process

From Figure 1.2, orange block shows the clarification and purification process area that involves in this research.

1.1 Problem Statement

The problem now at oil palm industry are high cost in turbine generate energy that use to heat up the settling tank. Other problem is time taken to finish the separation of CPO is quite long that usually take 1 hour, thus lower the production of purify palm oil with higher ratio of oil compare to sludge and non oily solid. In other hand employee that handle the processing of CPO can be decrease hence save the production cost. Using high temperature for CPO separation also will increasing equipment maintenance cost and create such harmful condition to mill workers.

Palm oil mill also faces challenge to maximize the oil collection in crude oil tank using optimum temperature supply from steam coil, so the clear oil can be skimmed out directly to oil tank without undergoing separation in clarifier tank as shown in Figure 3.1.

We also need to minimize the oil content pass through clarifier tank because there are some disadvantages. The disadvantages occur when crude oil pass through the 10.5 meter in height clarifier tank, worker need to climb to the high tank to adjust the adjustable level valve for clear oil skimming. The adjusting operation need to be done at least every one hour. Otherwise, the oil become thicker downward in the clarifier tank and remixes with the sludge. It will cause a lot of oil-sludge mixed discharge to underflow and then to the sludge tank. Longer time needed when the oil is reclarify in clarifier tank after have been separated with sludge and solid in centrifuge. (Figure 3.1)

1.2 Objectives

- To maximize oil production in oil palm mill.
- To determine optimum temperature, optimum residence time and effect of impeller in separation of crude palm oil (CPO) for separation to oil, sludge and non oily solid at clarification process area.

1.3 Scopes of study

To achieve the objective, scopes have been identified in this research. The scopes of this research are listed as below:-

(I) Identification of sludge oil separation problem.

(II) Identification of the right equipment for separation technique.

(III) Determination of optimum temperature

(IV) Determination of optimum residence time.

(V) Determination of stirrer in clarification tank

With constant feed rate, diameter and height of CPO in tank.

1.4 Rationale and Significance

The rationale for determine the optimum temperature and residence time of crude palm oil in settling tank while clarification process is to save energy and time while provide the heat.

The result from survey of 5 crude palm oil factories showed that electricity is the dominant source of energy for production process. Total energy consumption of all electric machines used in the production process is average 14.46 kWh/ton FFB. Palm oil mills in Thailand operate on cogeneration system using biomass residue as fuel in the boiler. The boiler produces high pressure and temperature steam, which expands in a backpressure steam turbine and produces enough electric power for the internal needs of the mill. The exhaust steam from the turbine goes to an accumulator which distributes the steam to various processes in the mill. The electricity used in this mill is distributed among 2 sources; turbine generator in factory and purchase from government supplier. The electricity generated in the factory is about 77.7 % of total electricity consumption. The power plant in the crude palm oil mill incorporates water tube boiler with a steaming capacity of 20 to 30 ton of steam/ hour. Fiber is used as fuel for generation of power in factory and used to supply the domestic purpose (3.3% of total electricity consumption).

Fuel used in the production process consists of 0.12 liters diesel oil/ ton FFB. Diesel oil is uses for diesel generator for start up boiler.

Thus, by knowing the optimum temperature in separation CPO, employer can save cost for energy supplying and reduce number of employee. We also may observe the effect of agitator in separation crude palm oil to oil, sludge and non oily solid. The impeller with speed of 5-10 rpm enhances the separation process.

CHAPTER 2

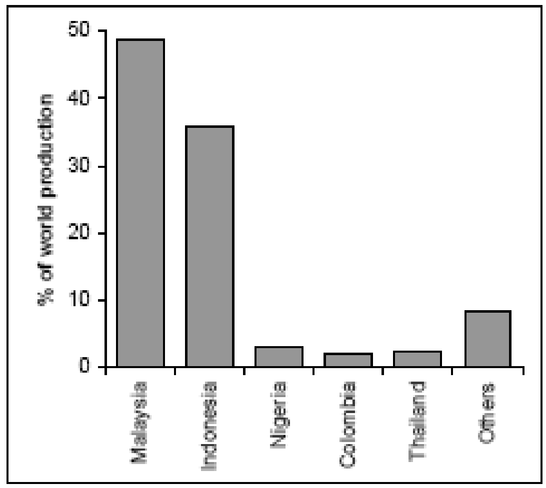
LITERATURE REVIEW

2.0 Definition of Palm Oil.

Palm oil is produced from the oil palm, primarily Elaeis guineensis, which originated in West Africa, but has adapted extremely well to other tropical lowland regions. The largest producer of palm oil is Malaysia, accounting for approximately 49% of global production. Indonesia ranks second, accounting for another 36%. Nigeria follows a distant third, with 2.9%. Oil palm plantations exist on a much smaller scale in several other African countries and in Central and South America (e.g., Colombia, Ecuador and Costa Rica). SE Asia is thus by far the main palm oil producing region accounting for in excess of 85% of world production (Figure 2.1). This is produced from over of 6 million hectares of plantation which represents nearly 80% of the world total oil palm plantation area. Between 1999/00 and 2002/03 Malaysian production of palm oil grew at 8.5% per year, whilst Indonesian production growth outstripped the world average, growing at 14.7% per year. *(IIED, ProForest, Rabobank, 2004).*

Palm oil contains an equal proportion of saturated and unsaturated fatty acids. It's particularly rich in the saturated palmitic acid (44%), with substantial amounts of the monounsaturated oleic acid (40%), and smaller amounts of polyunsaturated fatty acids (10%).

End users of palm oil are firstly producers of margarines, shortenings, cooking oils etc., such as Unilever and Vandemoortele, and secondly the users of such products. These are primarily found in the bakery business, confectionery, ice cream, snacks, the noodle industry and sectors using frying products.



Source: Oil World 2003 Oil World Annual. Mielke, Hamburg.

Figure 2.1 World Production of Palm Oil by Country in 2002-2003

2.1 Definition of Crude Palm Oil (CPO).

Crude Palm Oil (CPO) accounts for 21% of the global oils and fats supply, and 26% of the global vegetable oil supply. In comparison, soybeans yield 0.4 to 0.5 tones per hectare, and account for 25% of global oils and fats supply and 31% of global vegetable oil supply. Palm oil is the highest yielding oil crop per hectare. One hectare of oil palm yields 15–30 tones of fresh fruit, giving 2 to 7 tones of CPO, as well as PKO (Palm Kernel Oil) that is extracted from the kernels. Average production per tree is about 10 to 12 fruit bunches per year, each weighing between 20 and 30 kg. The harvested FFB are transported by truck from the plantation to the mill.

Crude palm oil has three main components, which are a mixture of oil and water, oil in water emulsions and water in oil emulsions. In clarifying station, the crude palm oil is separated into pure oil and sludge *(Stork, 1960).* An approximate average composition of screw pressed crude palm oil might be 64%oil, 24% water and 12% non oil solid *(Maycock, 1987).*

The properties of crude palm oil are shown in Figure 2.2. Examination of a sludge sample revealed the presence of oil droplets of sizes varying from less than 1 μm. The difference in specific gravity between sludge oil is practically constant at 0.1 throughout the temperature range from 40ºC to 100ºC *(Stork, 1960)*.

The largest solid impurity to be separated is the fiber and the smallest is the cellular debris. Due to the high ratio of solids to oil and the low ratio of water to solids in the crude oil from a screw press, water is added in order to enhance the settling efficiency. Experimental results show that the viscosity increases with the amount of water added up to 50% dilution. Beyond this point, the viscosity continuously falls with higher dilution but less steeply.

Crude palm oil is actually a mixture of about 92 to.95% oil, 4-5% oil soluble, up to 5% free fatty acids (FFA) and about 0.5% water, water soluble and solids. Generally the oil is made up of triglyceride (94-97%), diglyceride (2-3.5%) and monoglyceride (0.3-0.5%).*(Abdul Aziz, 2000).*

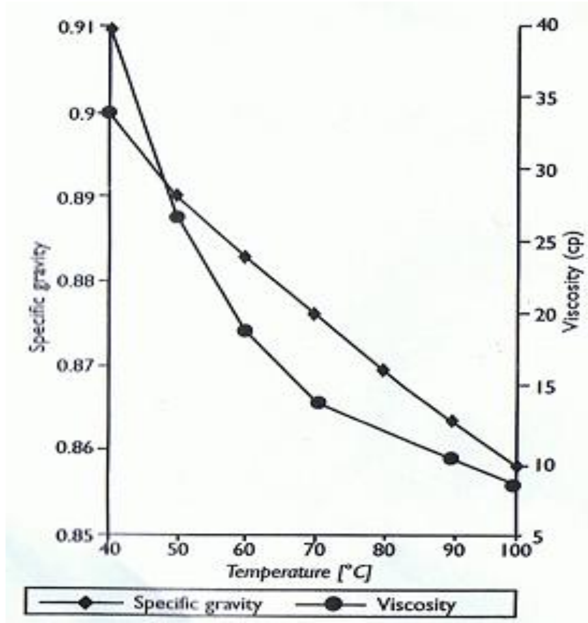


Figure 2.2 Crude Palm Oil Properties

Palm oil is a dark yellow to yellow-red oil (high carotene content) of vegetable origin obtained by pressing or boiling the flesh of the fruit of the oil palm. Palm oil differs from palm kernel oil, the latter being obtained from the kernels of the oil palm.

2.1.1 Chemical composition

Palm oil and palm kernel oil are composed of fatty acids, esterified with glycerol just like any ordinary fat. Both are high in saturated fatty acids, about 50% and 80%, respectively. The oil palm gives its name to the 16 carbon saturated fatty acid palmitic acid found in palm oil; monounsaturated oleic acid is also a constituent of palm oil while palm kernel oil contains mainly lauric acid. Palm oil is the largest natural source of tocotrienol, part of the vitamin E family. Palm oil is also high in vitamin K and dietary magnesium.

Napalm derives its name from naphthenic acid, palmitic acid and pyrotechnics or simply from a recipe using naphtha and palm oil.

The approximate concentration of fatty acids (FAs) in palm oil is as follows: *(Ang, Catharina Y.W., 1999)*

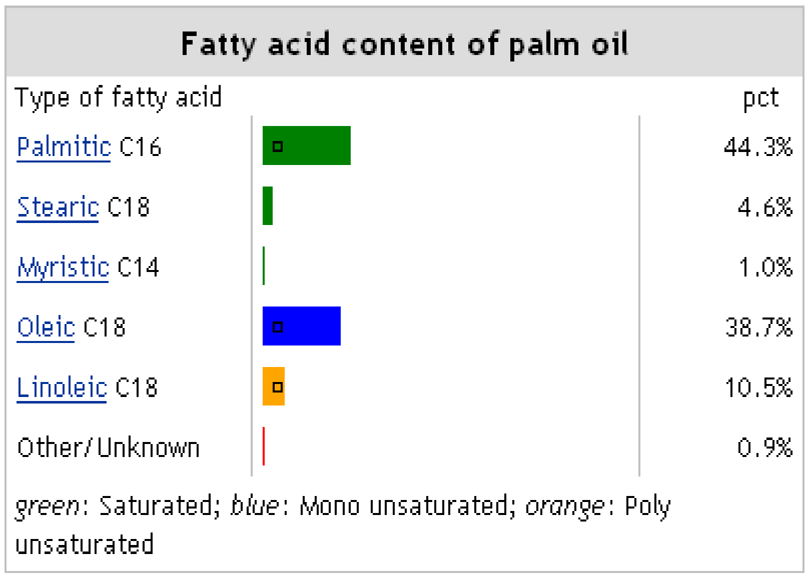
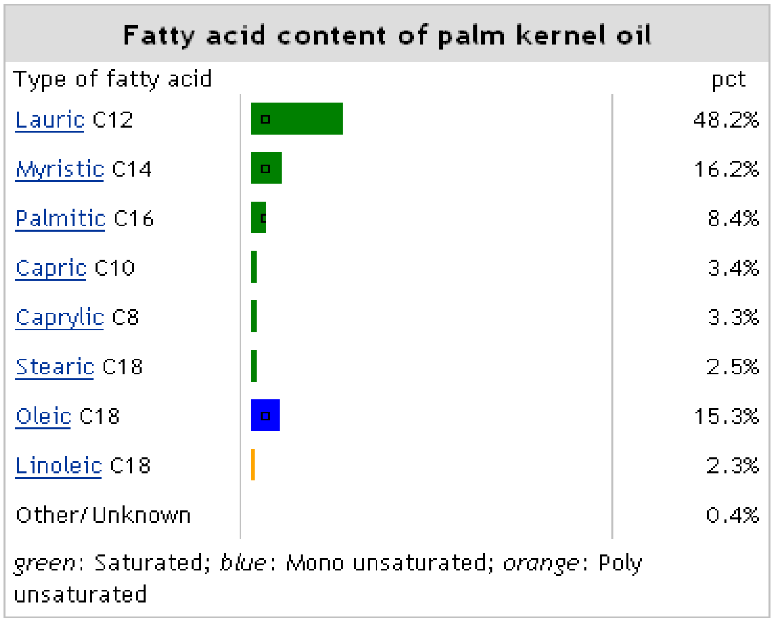


Figure 2.3 Fatty Acid Content of Palm Oil



Fatty acid content of palm kernel oil	
Type of fatty acid	pct
Lauric C12	48.2%
Myristic C14	16.2%
Palmitic C16	8.4%
Capric C10	3.4%
Caprylic C8	3.3%
Stearic C18	2.5%
Oleic C18	15.3%
Linoleic C18	2.3%
Other/Unknown	0.4%

green: Saturated; *blue*: Mono unsaturated; *orange*: Poly unsaturated

Figure 2.4 Fatty Acid Content of Palm Kernel Oil

Fatty acids are saturated and unsaturated aliphatic carboxylic acids with carbon chain length in the range of C6 up to C24. An example of a fatty acid is palmitic acid

$CH_3 – (CH_2)_{14} – COOH$

Figure 2.5 and 2.6 summarize the formation of storage oil of the palm fruit mesocarp cells.

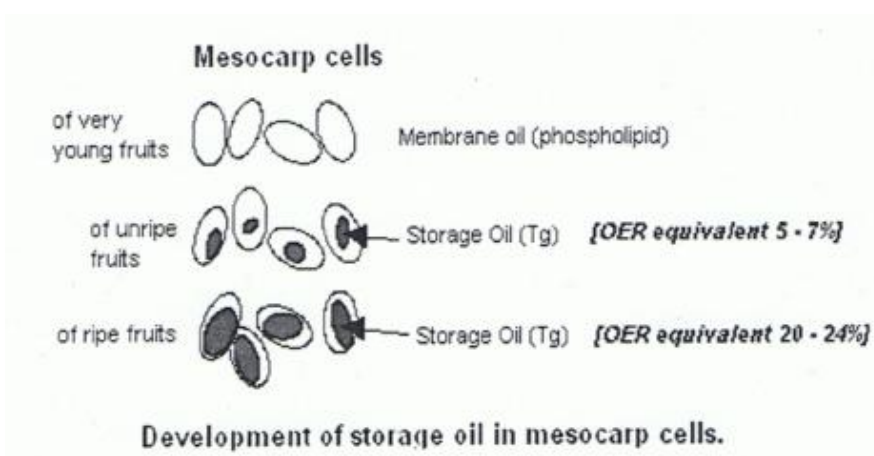


Figure 2.5 Development of storage oil in mesocarp cells.

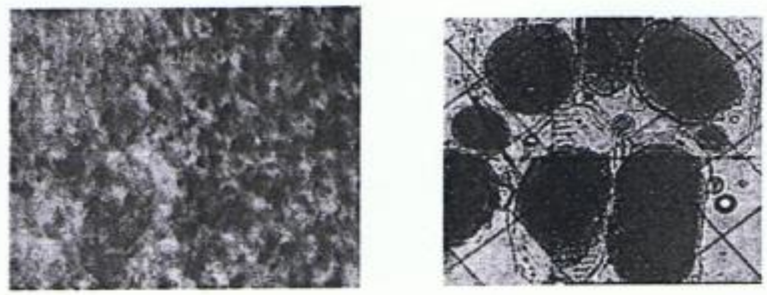


Figure 2.6 Young (left) and ripe (right) fruit mesocarp cells with oil globules.

Storage oil (Figure 2.6) also termed as oil globule or body occupies more two-third of volume of the cells.

Triglyceride (Tg) is a very stable molecule but only as long as it is confined within the cells. All mesocarp cells, in addition to having storage oil, contain lipase(hydrolytic enzyme). this enzyme has very specific function, i.e., breaking the triglyceride molecule back to fatty acids and glycerol through a process called hydrolysis. however this enzyme is heat liable. at above 80°C the enzyme is destroyed. Early deactivation of the enzyme will result in higher triglyceride recovery.

Harvesting and rough handling of harvested bunch especially at he platform and ramps will damage the cellular components of the fruits. When damage oil will be hydrolyzed to fatty acids and glycerol (Abdul Aziz and Tan, 1989).

In a complete hydrolysis (Figure 2.7 and 2.8), all the 3 fatty acids of the triglyceride are dislodged. the released fatty acid is termed as free fatty acid(FFA). In an incomplete hydrolysis one or two acids may be dislodged. the resultant products are glycerol with one fatty acid still attached (Figure2.8).

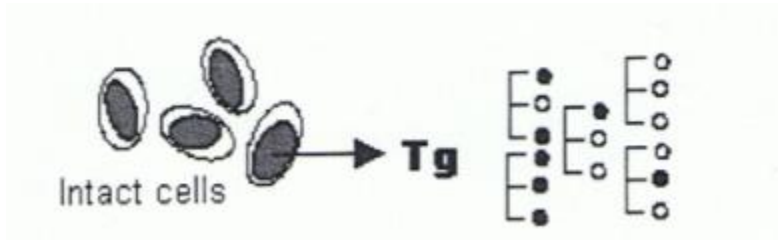


Figure 2.7 Storage oil of intact cells is purely triglyceride (Tg)

Storage oil released from broken cells contains the triglycerides (tg) and hydrolyzed products of Tg, namely diglycerides (Dg), Monoglycerides (Mg), free fatty acids (FFA) and glycerols. The amount and type of free fatty acids depend on the degree and type of damage experienced by the fruits. All cellular damages are attributed to physical actions.

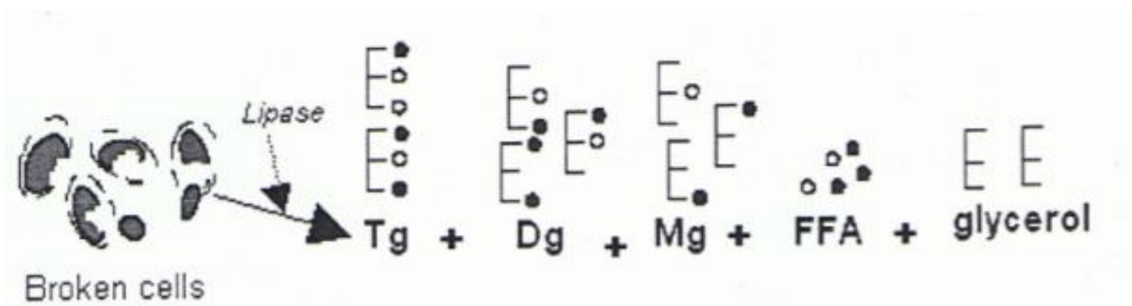


Figure 2.8 Traces the formation of di and monoglycerides, FFA and glycerol.

Free fatty acids (FFA). are the products of hydrolysis of TG and/or Dg and/or Mg. The FFA of CPO include the saturated lauric, myristic, palmitic and stearic acid ant the unsaturated oleic, linoleic and linolenic acid. (Figure 2.9)

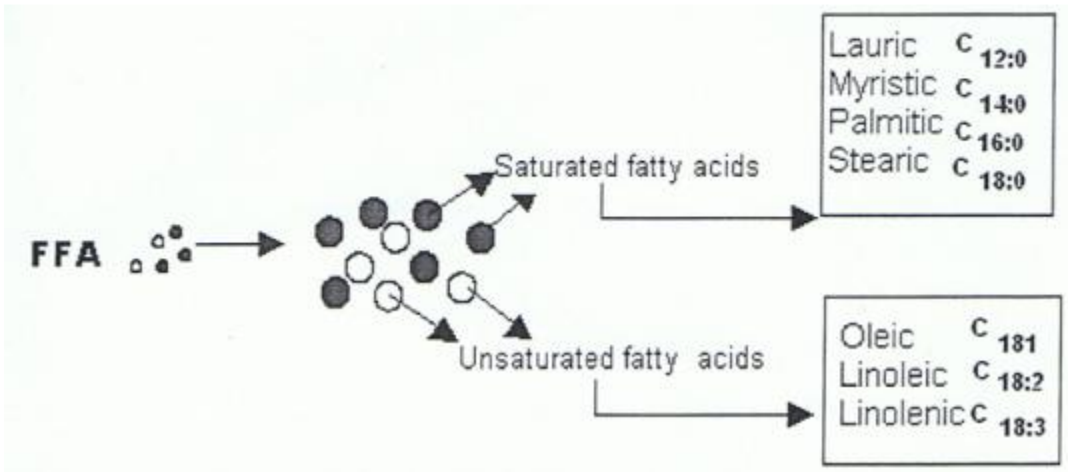


Figure 2.9 The hydrolyzed free fatty acid of CPO.

The presence microbial and moisture in crude oil allows hydrolysis. Nonetheless CPO must be allowed to have some moisture. Moisture gives some buffering effect to the oil to abstain from other chemical reactions. However its potent effect is only possible in the presence of moisture.

Glycerol esterified to two fatty acid molecules is called diglyceride, Whilst glycerol with one fatty acid is monoglycerides. The free fatty acids, formed via hydrolysis process, consist both the saturated and unsaturated fatty acids(Figure 2.9).

Whilst saturated fatty acids are very stable, the unsaturated fatty acids are easily oxidized. These oxidation products include the peroxides, ketones and aldehydes.(Figure 2.10).

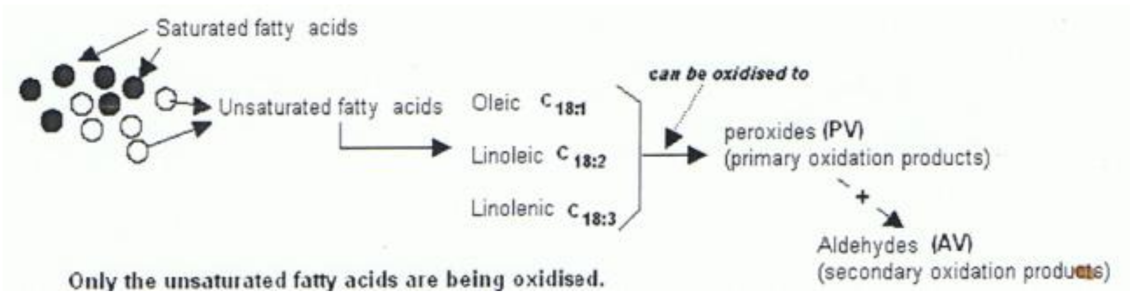


Figure 2.10 Only the saturated fatty acids are oxidized.

The best quality CPO is one that contains the highest amount of triglycerides. Tryglycerode (Appendix D) is a molecule made up of glycerol holding 3 fatty acids.The variable fatty acids (both saturated and unsaturated acids) thats constitute the triglyceride molecule. (Table 2.1)., permits each triglyceride to attain its specific physical (melting and boiling points) properties (Figure 2.11). Stearic-stearic-stearic (SSS) or stearic-palmitic-stearic (SPS) or palmitic-palmitic-palmitic (PPP) trygliceride is solid at room temperature, whilst oleic-oleic-oleic (OOO) or palmitic-oleic-oleic (POO) or oleic-linleic-oleic (OLO) triglyceride is liquid. Stearic- oleic-stearic (SOS), Palmitic-palmitic-oleic-palmitic (POP) and Lauric-oleic-lauric (LOL) will be in semi solid. Significant quantity of Dg and Mg in the oil will affect the efficiency of crystallization of the designated triglyceride.

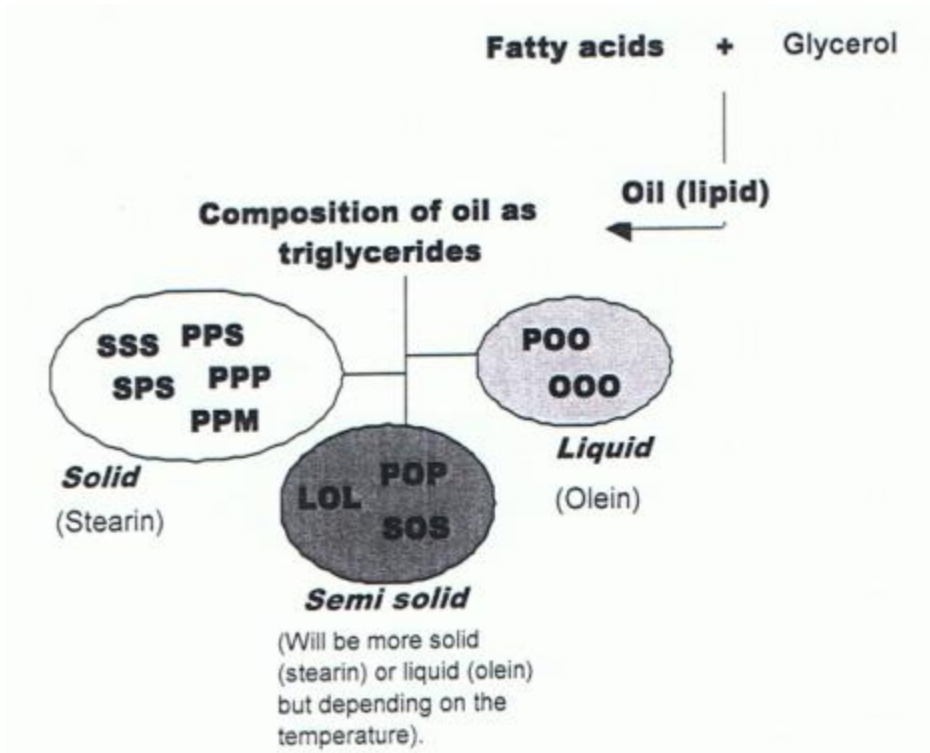


Figure 2.11 Summarize of the effect of cooling on the different triglycerides in palm oil.

Table 2.1 The unsaturated acid mono and diglycerides with high melting will crystallize if cooled below 20°C.

		Melting Point(Centrigrade)			
Fatty acid	**Carbon No.**	**as acid**	**as 1-Mg**	**as 1,3-Dg**	**as (Tg) triglyceride**
Lauric	12	44.2			46.4
Myristic	14	54.4			57.0
Palmitic	16	62.9	77	76.3	63.5
Stearic	18	69.6	81.5	79.4	73.1
Oleic	18:1	16.3	35.2	21.5	5.5
Linoleic	18:2	-6.5	15.7	-2.6	-13.1
Linolenic	18:3	-12.8			-24.2

2.2 Life Cycle Inventory (LCI)

Inventory data collected over of 3 months from each mill is divided into environmental inputs and output. the data is then extrapolated to quantify the inputs from the environment and outputs to the environment for every one ton of CPO produced to create LCI as shown in Table 2.2 and 2.3. Using LCI data which consists of input and output of the system boundary for every 1 ton of CPO produces, the Life Cycle Impact Assessment (LCIA) is conducted using the Simapro Software version 6.0. The software is an European software with European Data. However, the software is generic and Malaysian data has been input to conduct the study. *(Vijaya S, Ma A.N, Choo Y.M & Nik Meriam N.S)*

Table 2.2 Inventory Data of 6 Mills-Environmental Inputs for Every 1 t of CPO Produced

Mill	A	B	C	D	E	F
Type	Private	Plantation	Private	Plantation	Plantation	Plantation
Processing Capacity (t/hr)	40	45	90	20	70	30
Fuel flow rate (t/hr)	5.60	4.88	9.00	2.10	13.00	3.20
Steam output (t/hr)	19.0	25.0	35.0	11.0	50.0	15.0
Boiler type	Vickers Hoskins	Mechmar	Vickers Hoskins	IBAE	Vickers Hoskins	Allied Equipment
ENVIRONMENTAL INPUTS						
Fresh Fruit Bunch (t)	5.34	5.27	5.39	4.93	4.87	5.07
Power consumption from Turbine (kWh)	**106.73**	**105.48**	**107.71**	**98.59**	**97.36**	**101.38**
Power consumption from Grid (kWh)	0.18	2.95	0.10	2.00	0.00	1.99
Diesel consumption for Mill (L)	1.29	2.92	0.38	2.17	4.51	0.00
Diesel consumption for vehicles in mill (L)	2.60	0.84	2.10	0.28	0.68	0.15
Boiler fuel						
Mesocarp fibre(t)	**0.52**	**0.47**	**0.49**	**0.43**	**0.55**	**0.57**
Shell (t)	**0.22**	**0.20**	**0.05**	**0.11**	**0.36**	**0.24**
Boiler water consumption (L)	2.54	3.43	2.12	2.79	3.50	3.83
Steam input for sterilization (t)	**3.47**	**3.43**	**3.50**	**3.20**	**3.16**	**3.29**
Steam input to turbine (t)	2.54	3.43	2.12	2.79	3.50	3.83

Bolded rows indicate renewable energy or recycled materials

Table 2.3 Inventory Data of 6 Mills-Environmental Outputs for Every 1 t of CPO Produced

Mill	A	B	C	D	E	F
ENVIRONMENTAL OUTPUTS						
Mesocarp Fibre (t)	0.12	0.16	0.16	0.16	0.04	0.04
Shell (t)	0.15	0.17	0.32	0.24	0.00	0.11
EFB (t)	1.23	1.21	1.24	1.13	1.12	1.17
POME(m^3)	3.20	3.16	3.23	2.96	2.92	3.04
Methane from POME pond (m^3)	58.27	57.59	58.81	53.83	53.16	55.35
CO_2 from POME pond (m^3)	31.38	31.01	31.67	28.99	28.62	29.81
Boiler ash (t)	0.02	0.02	0.02	0.01	0.01	0.02
Flue Gaseous from stack						
Particulate Matter (kg)	0.11	0.14	0.56	0.06	0.45	0.14
CO (kg)	0.06	0.06	0.11	0.02	0.14	0.05
CO_2 (kg)	56.87	56.05	114.59	11.56	161.20	40.05
SO_x (kg)	0.001	0.001	0.002	0.0004	0.003	0.001
NO_x (kg)	0.12	0.09	0.20	0.04	0.20	0.07
RECYCLED WASTE						
EFB	Shredded& used as fuel	Mulching	Mulching	Mulching	Mulching	Mulching
POME	Treated & sold as fertilizer	Treated and used as fertilizer	Treated & discharged	Treated and used as fertilizer	Treated and used as fertilizer	Treated and used as fertilizer
Excess Mesocarp fibre & shell	Sold as fuel	Sold as fuel	Sold as fuel	Sold as fuel	-	Sold as fuel
Boiler ash	Land application	Land application	Land application	Land application	Land application	Land application